

## 8.5: Electronic Structure and the Periodic Table

### Learning Objectives

- Relate the electron configurations of the elements to the shape of the periodic table.
- Determine the expected electron configuration of an element by its place on the periodic table.

In Chapter 3, we introduced the periodic table as a tool for organizing the known chemical elements. A periodic table is shown in Figure 8.5.1. The elements are listed by atomic number (the number of protons in the nucleus), and elements with similar chemical properties are grouped together in columns.

1 H 1.00794																	2 He 4.002602	
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797	
11 Na 22.989770	12 Mg 24.3050											13 Al 26.581538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948	
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6534	29 Cu 63.545	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.504	36 Kr 83.80	
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29	
55 Cs 132.90545	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.58038	84 Po (209)	85 At (210)	86 Rn (222)	
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 (269)	111 (272)	112 (277)			114 (289)	116 (289)			118 (293)
58 Ce 140.116	59 Pr 140.50765	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.92534	66 Dy 162.50	67 Ho 164.93032	68 Er 167.26	69 Tm 168.93421	70 Yb 173.04	71 Lu 174.967					
90 Th 232.0381	91 Pa 231.035888	92 U 238.0289	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)					

Figure 8.5.1: The Periodic Table

Why does the periodic table have the structure it does? The answer is rather simple, if you understand electron configurations, the shape of the periodic table mimics the filling of the subshells with electrons.

*The shape of the periodic table mimics the filling of the subshells with electrons.*

Let us start with H and He. Their electron configurations are  $1s^1$  and  $1s^2$ , respectively; with He, the  $n = 1$  shell is filled. These two elements make up the first row of the periodic table (Figure 8.5.2)

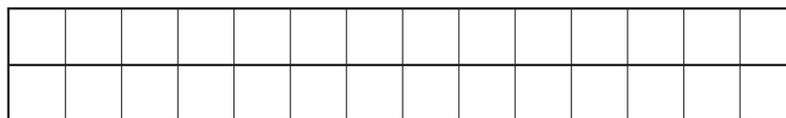
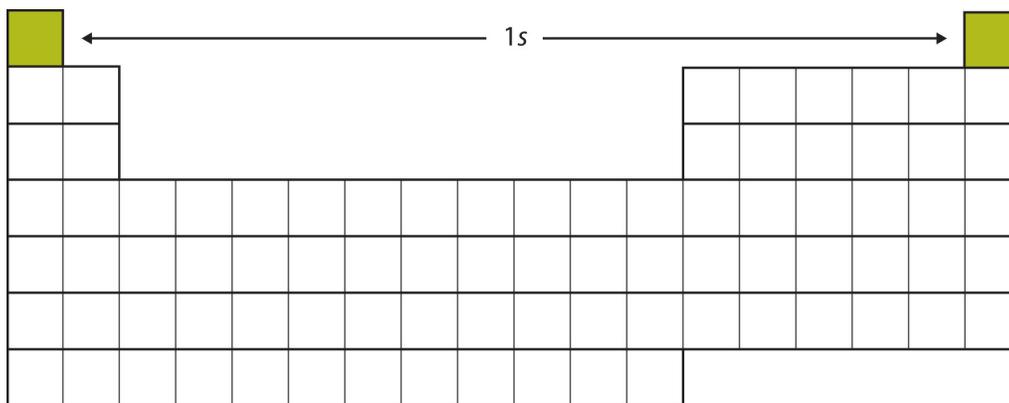


Figure 8.5.2: The 1s Subshell. H and He represent the filling of the 1s subshell.

The next two electrons, for Li and Be, would go into the 2s subshell. Figure 8.5.3 shows that these two elements are adjacent on the periodic table.

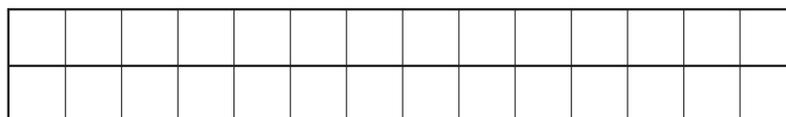
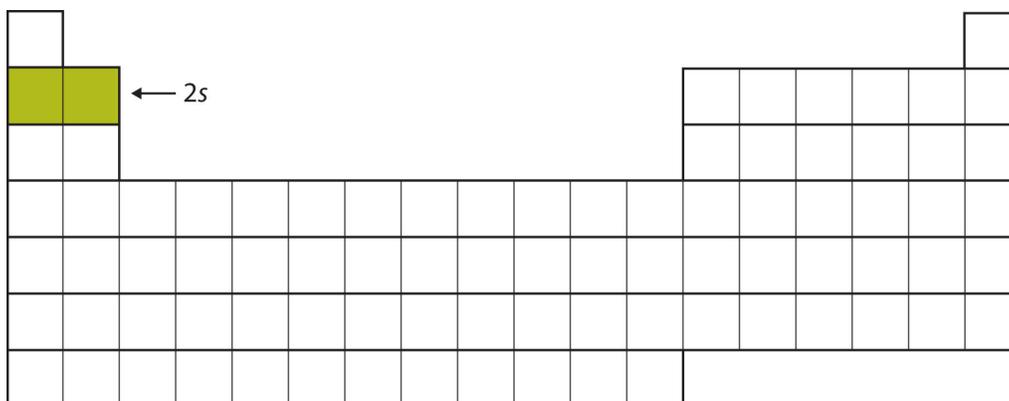


Figure 8.5.3: The 2s Subshell. In Li and Be, the 2s subshell is being filled.

For the next six elements, the  $2p$  subshell is being occupied with electrons. On the right side of the periodic table, these six elements (B through Ne) are grouped together (Figure 8.5.4).

A periodic table diagram where the 2p subshell is highlighted in green. An arrow labeled "2p" points to the green cells. The highlighted cells are in the second row, columns 13 through 18.

A 2x10 grid representing the 2p subshell.

Figure 8.5.4: The 2p Subshell. For B through Ne, the 2p subshell is being occupied.

The next subshell to be filled is the 3s subshell. The elements coinciding this subshell being filled, Na and Mg, are back on the left side of the periodic table (Figure 8.5.5).

A periodic table diagram where the 3s subshell is highlighted in green. An arrow labeled "3s" points to the green cells. The highlighted cells are in the third row, columns 1 and 2.

A 2x10 grid representing the 3s subshell.

Figure 8.5.5: The 3s Subshell. Now the 3s subshell is being occupied.

Next, the 3p subshell is filled with the next six elements (Figure 8.5.6).

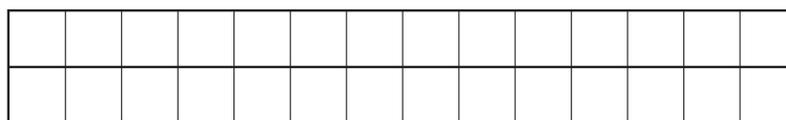
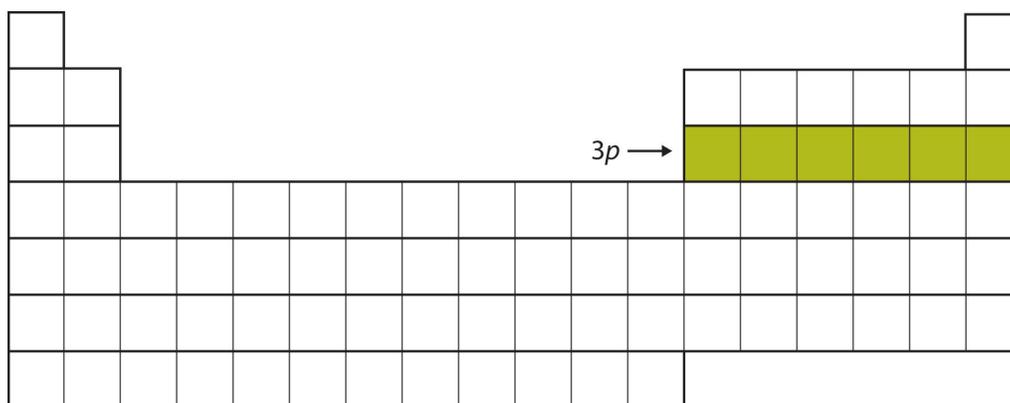


Figure 8.5.6: The 3p Subshell. Next, the 3p subshell is filled with electrons.

Instead of filling the 3d subshell next, electrons go into the 4s subshell (Figure 8.5.7).

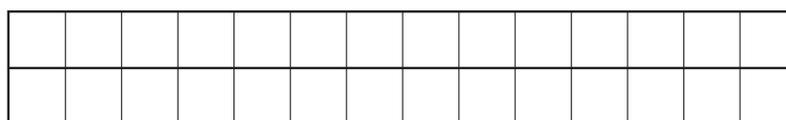
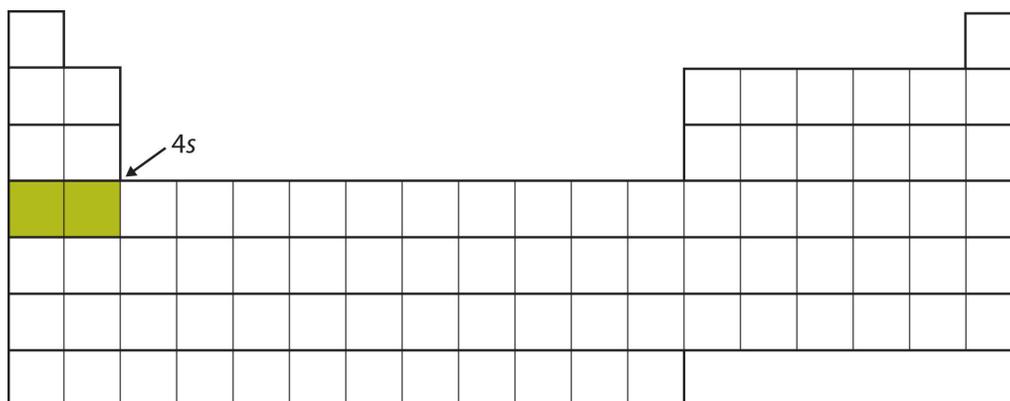


Figure 8.5.7: The 4s Subshell. The 4s subshell is filled before the 3d subshell. This is reflected in the structure of the periodic table.

After the 4s subshell is filled, the 3d subshell is filled with up to 10 electrons. This explains the section of 10 elements in the middle of the periodic table (Figure 8.5.8).

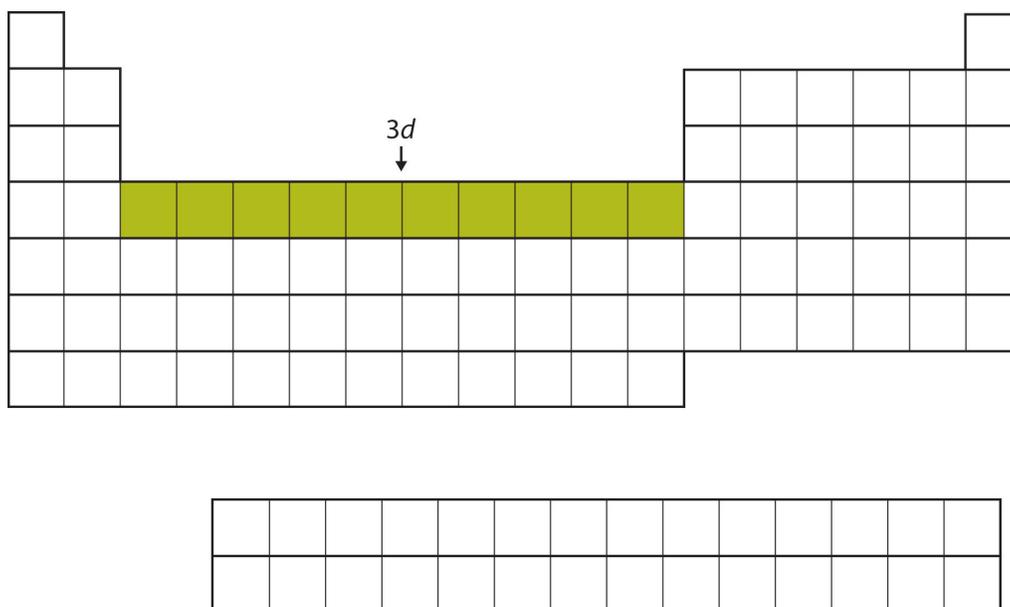


Figure 8.5.8: The 3d Subshell. The 3d subshell is filled in the middle section of the periodic table.

And so forth. As we go across the columns of the periodic table, the overall shape of the table outlines how the electrons are occupying the shells and subshells.

The first two columns on the left side of the periodic table are where the *s* subshells are being occupied. Because of this, the first two rows of the periodic table are labeled the **s block**. Similarly, the **p block** is the right-most six columns of the periodic table, the **d block** is the middle 10 columns of the periodic table, while the **f block** is the 14-column section that is normally depicted as detached from the main body of the periodic table. It could be part of the main body, but then the periodic table would be rather long and cumbersome. Figure 8.5.9 shows the blocks of the periodic table.

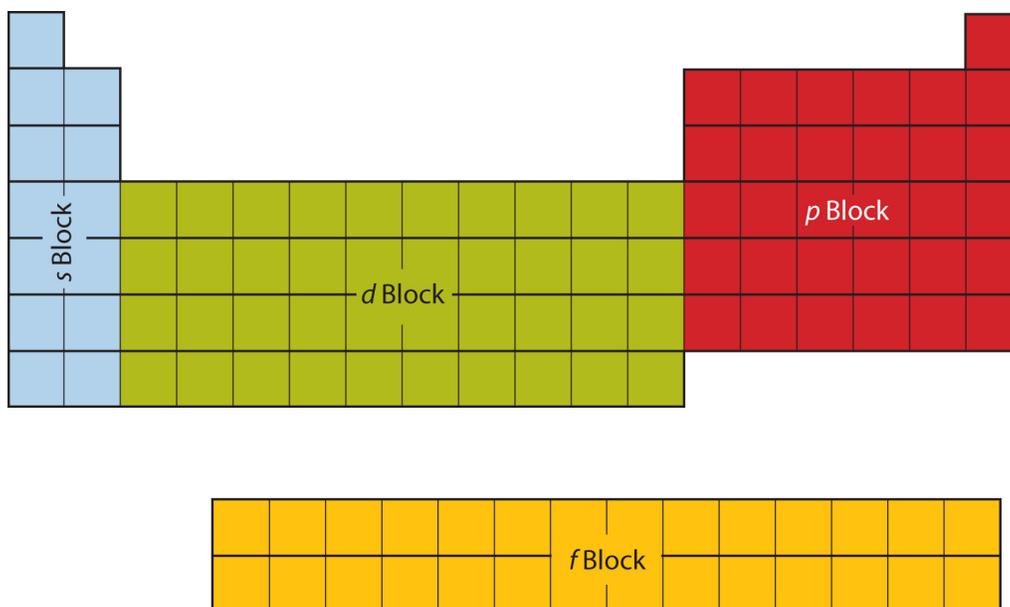


Figure 8.5.9: Blocks on the Periodic Table. The periodic table is separated into blocks depending on which subshell is being filled for the atoms that belong in that section.

Empty periodic table, separated into 4 different colored blocks. S block is blue, d block is green, p block is red and f block is orange.

The electrons in the highest-numbered shell, plus any electrons in the last unfilled subshell, are called **valence electrons**; the highest-numbered shell is called the **valence shell**. (The inner electrons are called *core electrons*.) The valence electrons largely control the chemistry of an atom. If we look at just the valence shell's electron configuration, we find that in each column, the valence shell's electron configuration is the same. For example, take the elements in the first column of the periodic table: H, Li,

Na, K, Rb, and Cs. Their electron configurations (abbreviated for the larger atoms) are as follows, with the valence shell electron configuration highlighted:

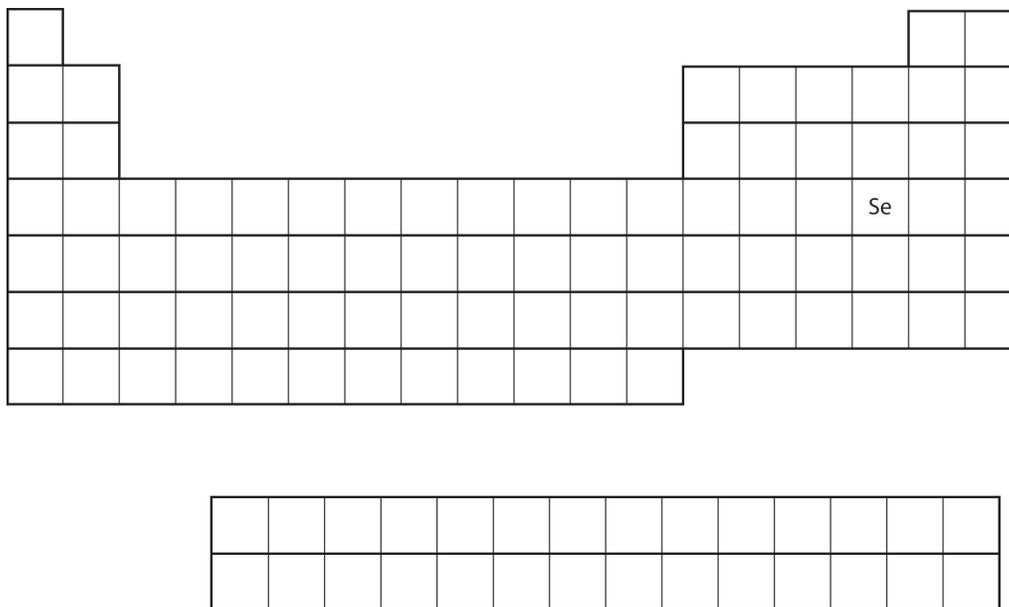
Table with two columns and 6 rows. The first column on the left has various elements in the rows underneath. The second column on the right has the different corresponding electron configurations for the specified element in the rows underneath.

H:	$1s^1$
Li:	$1s^2 2s^1$
Na:	$[\text{Ne}]3s^1$
K:	$[\text{Ar}]4s^1$
Rb:	$[\text{Kr}]5s^1$
Cs:	$[\text{Xe}]6s^1$

They all have a similar electron configuration in their valence shells: a single  $s$  electron. Because much of the chemistry of an element is influenced by valence electrons, we would expect that these elements would have similar chemistry—and they do. The organization of electrons in atoms explains not only the shape of the periodic table, but also the fact that elements in the same column of the periodic table have similar chemistry.

The same concept applies to the other columns of the periodic table. Elements in each column have the same valence shell electron configurations, and the elements have some similar chemical properties. This is strictly true for all elements in the  $s$  and  $p$  blocks. In the  $d$  and  $f$  blocks, because there are exceptions to the order of filling of subshells with electrons, similar valence shells are not absolute in these blocks. However, many similarities do exist in these blocks, so a similarity in chemical properties is expected.

Similarity of valence shell electron configuration implies that we can determine the electron configuration of an atom solely by its position on the periodic table. Consider Se, as shown in Figure 8.5.10. It is in the fourth column of the  $p$  block. This means that its electron configuration should end in a  $p^4$  electron configuration. Indeed, the electron configuration of Se is  $[\text{Ar}]4s^2 3d^{10} 4p^4$ , as expected.



The figure shows a simplified periodic table with the following structure:

- Row 1: 2 boxes (H, He)
- Row 2: 2 boxes (Li, Be) followed by a gap, then 6 boxes (B, C, N, O, F, Ne)
- Row 3: 2 boxes (Na, Mg) followed by a gap, then 6 boxes (Al, Si, P, S, Cl, Ar)
- Row 4: 10 boxes (K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni) followed by a gap, then 6 boxes (Cu, Zn, Ga, Ge, As, Se, Br, Kr). Selenium (Se) is labeled in the 4th column of this row.
- Row 5: 10 boxes (Rb, Sr, Y, Zr, Nb, Mo, Tc, Ru, Rh, Pd) followed by a gap, then 6 boxes (Ag, Cd, In, Sn, Sb, Te, I, Xe).
- Row 6: 10 boxes (Cs, Ba, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd) followed by a gap, then 6 boxes (Au, Hg, Tl, Pb, Bi, Po, At, Rn).

Figure 8.5.10: Selenium on the Periodic Table

#### ✓ Example 8.5.1

From the element's position on the periodic table, predict the valence shell electron configuration for each atom (Figure 8.5.11).

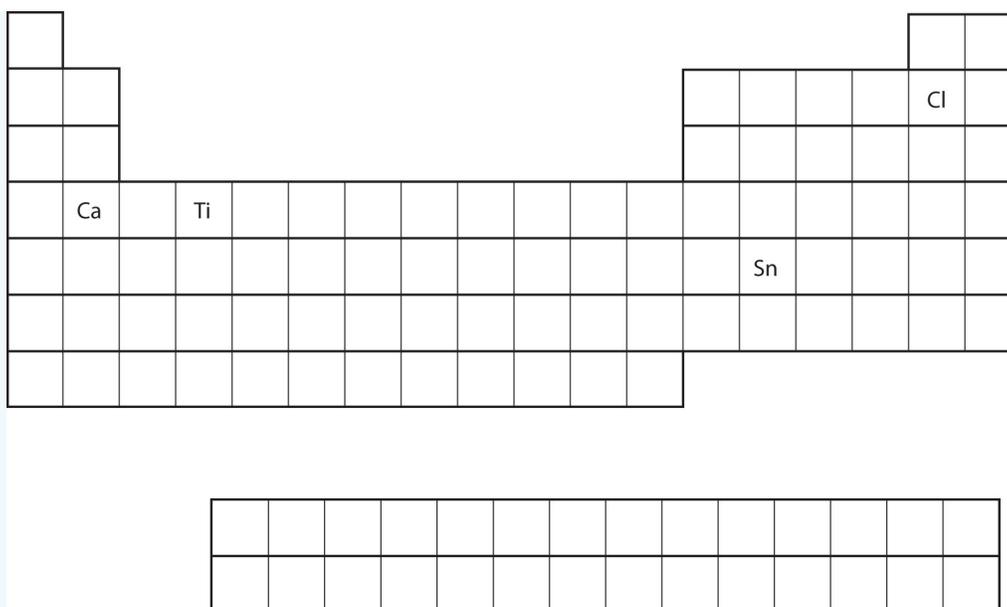


Figure 8.5.11: Various Elements on the Periodic Table

1. Ca
2. Sn

#### Solution

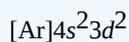
1. Ca is located in the second column of the  $s$  block. We would expect that its electron configuration should end with  $s^2$ . Calcium's electron configuration is  $[\text{Ar}]4s^2$ .
2. Sn is located in the second column of the  $p$  block, so we expect that its electron configuration would end in  $p^2$ . Tin's electron configuration is  $[\text{Kr}]5s^24d^{10}5p^2$ .

#### ? Exercise 8.5.1

From the element's position on the periodic table, predict the valence shell electron configuration for each atom. Figure 8.5.11.

- a. Ti
- b. Cl

#### Answer a



#### Answer b



#### 📌 Food and Drink Application: Artificial Colors

The color of objects comes from a different mechanism than the colors of neon and other discharge lights. Although colored lights produce their colors, objects are colored because they preferentially reflect a certain color from the white light that shines on them. A red tomato, for example, is bright red because it reflects red light while absorbing all the other colors of the rainbow.

Many foods, such as tomatoes, are highly colored; in fact, the common statement "you eat with your eyes first" is an implicit recognition that the visual appeal of food is just as important as its taste. But what about processed foods?

Many processed foods have food colorings added to them. There are two types of food colorings: natural and artificial. Natural food colorings include caramelized sugar for brown; annatto, turmeric, and saffron for various shades of orange or yellow; betanin from beets for purple; and even carmine, a deep red dye that is extracted from the cochineal, a small insect that is a parasite on cacti in Central and South America. (That's right—you may be eating bug juice!)

Some colorings are artificial. In the United States, the Food and Drug Administration currently approves only seven compounds as artificial colorings in food, beverages, and cosmetics:

- FD&C Blue #1: Brilliant Blue FCF
- FD&C Blue #2: Indigotine
- FD&C Green #3: Fast Green FCF
- RD&C Red #3: Erythrosine
- FD&C Red #40: Allura Red AC
- FD&C Yellow #5: Tartrazine
- FD&C Yellow #6: Sunset Yellow FCF

Lower-numbered colors are no longer on the market or have been removed for various reasons. Typically, these artificial colorings are large molecules that absorb certain colors of light very strongly, making them useful even at very low concentrations in foods and cosmetics. Even at such low amounts, some critics claim that a small portion of the population (especially children) is sensitive to artificial colorings and urge that their use be curtailed or halted. However, formal studies of artificial colorings and their effects on behavior have been inconclusive or contradictory. Many people continue to enjoy processed foods with artificial coloring (like those shown in the accompanying figure).



Artificial food colorings. Artificial food colorings are found in a variety of food products, such as processed foods, candies, and egg dyes. Even pet foods have artificial food coloring in them. (CC by 2.0, [Matthew Bland](#) via [Flickr](#).)

## Summary

The arrangement of electrons in atoms is responsible for the shape of the periodic table. Electron configurations can be predicted by the position of an atom on the periodic table.

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